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AN ASSESSMENT OF EMISSIONS FROM A HAZARDOUS WASTE INCINERATION FACILITY*

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ABSTRACT

The exposure in a nearby population to volatile organic compounds (VOCs) from emissions of a municipal hazardous waste incinerator is determined by measuring the emission rates and estimating the dispersion of those pollutants over the surrounding community. Measurements of fugitive VOC emissions from leaky pipe fittings, flanges, pumps, and valves are made. VOC emissions from the stack and air pollution control devices are also measured. An emission assessment is then performed to determine the percentage concentration and population exposure associated with selected emissions from each source at the facility. Results indicate that, in this particular case, fugitive and stack emissions do not contribute significantly to pollutant concentration and population exposure. Further, data for specific constitutents of the VOC emissions also show extremely low concentrations and exposure, but these results are based on only a partial analysis and additional qualitative emission analyses are required.

INTRODUCTION

Incineration of hazardous wastes produces stack and nonstack emissions. Until now, the Environmental Protection Agency (EPA) has been concentrating on minimizing stack emissions. EPA has begun to suspect, however, that stack emissions may not be the predominant source of air emissions from hazardous waste incinerators. To better characterize all sources of air pollution from these facilities, EPA has entered into a three-year interagency agreement with the Department of Energy at Oak Ridge National Laboratory (DOE/ORNL) to determine the relative magnitude and significance of stack and nonstack emissions, and to ultimately evaluate potential control techniques.

Although stack testing is not new and fugitive emissions measurements have been made at oil refineries and chemical plants, stack and fugitive emissions measurements have not been made simultaneously at the same hazardous waste facility. Since this is essential for comparison, EPA decided to do it at the first available opportunity.

This paper presents results of an experiment conducted at the liquid fluid incinerator operated by Cincinnati's Metropolitan Sewer District (MSD) in July 1981. The purpose of the experiment was to determine for one set of conditions the population exposure to hydrocarbons that are emitted by an incinerator. Hydrocarbon emission rates from both stack and nonstack sources were measured. Atmospheric concentrations were estimated from these measurements using the Industrial Source Complex Dispersion (ISC) model (3). Population exposure to these concentrations were then calculated. Using toxicity data for six principal organic hazardous con-

stituents (POHCs) contained in the hydrocarbon emissions, the significance of these exposures was assessed.

This experiment represents the first attempt EPA has made to measure both stack and nonstack emissions simultaneously at one incinerator. Consequently, it is premature to draw broad general conclusions about the relative significance of stack and fugitive emissions at hazardous waste incinerators from the work completed thus far.

Source Term Development

The Cincinnati MSD incinerator is a two-year old facility with a thermal capacity of 3.50×10^{10} cal/hr (139×10^6 Btu/hr). It consists of a rotary kiln and a liquid injection furnace in parallel followed by a secondary combustion chamber, quench, high pressure venturi scrubber, and packed bed absorber. Nitrogen blanked tanks, 9.46×10^4 l (25,000 gallons), allow for storage of liquid waste which is typically delivered by tank truck.

Prior to conducting field measurements, fugitive emission rates were estimated using emission factors for valves, flanges, and pumps developed from studies of oil refineries (8). These calculations indicated that, indeed, fugitive emissions may greatly exceed stack emissions at 99.99 percent DRE and may be significant at lower destruction and removal efficiencies.

Results of these calculations are shown in Figure 1 (7). To gather some preliminary information to determine the validity of these calculations, EPA monitored the fugitive emissions at the Cincinnati incinerator during a trial burn at which stack testing was conducted.

During the trial burn, approximately 3.41×10^5 l (90, 000 gallons) of waste containing chlorinated compounds as well as alcohols, carbonyl compounds, and C_6 - C_8 alkanes from nearby landfills were burned. Hydrocarbon stack emissions, measured as methane, were determined using the Dohrmann DC-50 continuous monitor as a direct flame ionization detector (1). Fugitive hydrocarbon emissions were determined by screening each valve, vent, flange, and pump seal in the storage, loading dock, and at the feed inlets to the incinerators using the Century Systems OVA 108 and OVA 128 portable organic vapor analyzers and EPA standard Reference Method 21 (6). Both instruments were calibrated to methane and indicated hydrocarbon concentrations in ppm methane. These readings were converted to emission rates in g/hr using correlations developed in another study (5).

Modeling Methodology

The impact of these emissions on the surrounding population was assessed using the Industrial Source Complex Dispersion Model. Together with local meteorological and population data supplied by ORNL, the model can be used to assess the air quality impact of emissions from area and point sources associated with an industrial complex. The model assumes Gaussian plume dispersion and can account for the effects of elevated terrain surrounding the incinerator and building wake effects. Using meteorological data and incinerator design, operation, and emission release data (Table 1), the ISC computer model was run to estimate downwind concentrations at 176 receptors (16 directions and 11 distances) (see Figure 2). Each receptor point was defined by the intersection of 1 of 11 rings of various diameters centered around the incinerator and 1 of 16 radial lines emanating from the complex center. Each radial was separated by 22.5° intervals beginning with due north (0°) and proceeding clockwise. The 11 ring diameters were 0.2, 0.3, 0.5, 0.7, 1.0, 2.0, 3.0, 5.0, 7.0, 10.0, and 15.0 km. These distances were chosen to span the greater Cincinnati metropolitan area.

To account for Cincinnati's hilly terrain, elevations of each receptor point were taken from topographic maps. At 91 of the 176 receptor locations where the elevation exceeded the stack height, the stack height elevation less 30.5 cm (1 ft) was used. Such treatment may be simplified, but it's conservative in that the concentration calculated at this elevation would be the maximum experienced at that particular location.

The concentration calculated by ISC were than coupled with 1980 census data to give population exposures (2, 4).

RESULTS

Downwind concentration estimates at the 176 receptors were calculated for total

PERCENTAGE FUGITIVE EMISSIONS AS A FUNCTION OF % DRE

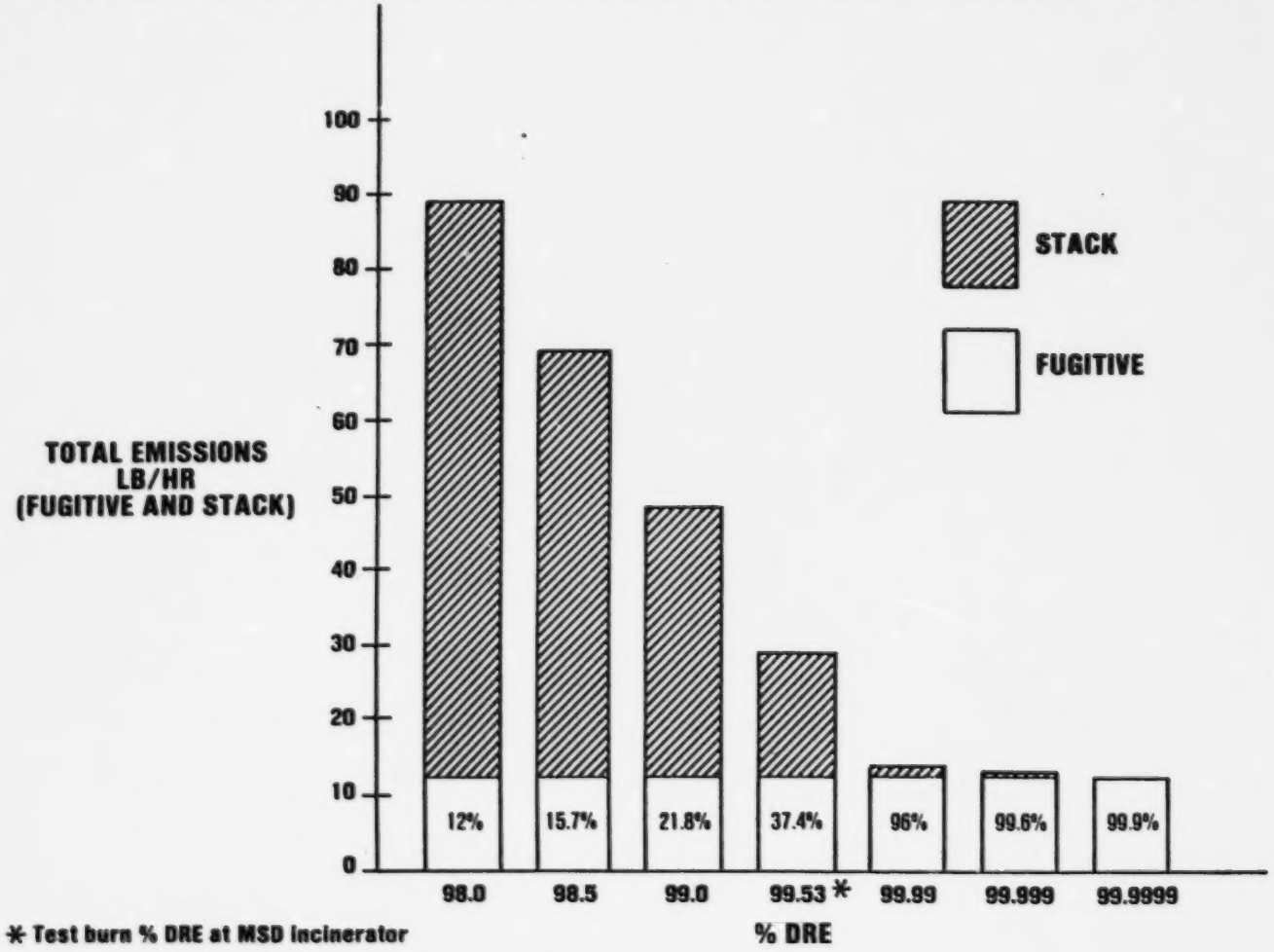

FIGURE 1

Table 1. Summary of source values used to represent the Cincinnati MSD incinerator

Source name	Representation	Component number	Size (m^2)	Coordinates of center (m)	Release height (m)	Release velocity (m/s)	Gas temperature (K)	Pollutant emission rates, g/s[b,c]						
								Total HC[d]	$CHCl_3$[e]	CCl_4[f]	C_2Cl_4[g]	HCCP[h]	C_2Cl_6[i]	C_6Cl_6[j]
Stack	1 stack	1	3.4[a]	35.0, 0.0	27.4	6.40	366.5	6.64×10^{-1}	5.17×10^{-4}	7.01×10^{-5}	3.05×10^{-4}	6.52×10^{-6}	1.77×10^{-5}	1.64×10^{-5}
Structure	2 area sources	1	62.8	26.5, 4.0	20.1			1.43×10^{-3}	1.99×10^{-6}	8.10×10^{-7}	4.30×10^{-8}	2.60×10^{-9}	5.77×10^{-10}	1.14×10^{-10}
		2	62.8	18.5, 4.0	20.1			1.43×10^{-3}	1.99×10^{-6}	8.10×10^{-7}	4.30×10^{-8}	2.60×10^{-9}	5.77×10^{-10}	1.14×10^{-10}
Tank farm	3 area sources	1	455.2	-33.6, 9.5	6.1			1.04×10^{-2}	1.44×10^{-5}	5.87×10^{-6}	3.11×10^{-7}	1.88×10^{-8}	4.18×10^{-9}	8.29×10^{-10}
		2	455.2	-54.9, 9.5	6.1			1.04×10^{-2}	1.44×10^{-5}	5.87×10^{-6}	3.11×10^{-7}	1.88×10^{-8}	4.18×10^{-9}	8.29×10^{-10}
		3	455.2	-76.3, 9.5	6.1			1.04×10^{-2}	1.44×10^{-5}	5.87×10^{-6}	3.11×10^{-7}	1.88×10^{-8}	4.18×10^{-9}	8.29×10^{-10}
TOTAL								5.98×10^{-1}	5.64×10^{-4}	8.93×10^{-5}	3.06×10^{-4}	6.58×10^{-6}	1.77×10^{-5}	1.64×10^{-5}

[a] Stack area corresponds to an inner diameter of 2.08 m.

[b] Stack emission rates calculated from stack sampling.

[c] Fugitive emission rates calculated from waste chemical analyses.

[d] Total hydrocarbon.

[e] Chloroform – specified primary organic hazardous constituent (POHC).

[f] Carbon tetrachloride – specified POHC.

[g] Tetrachlorethene – specified POHC.

[h] Hexachlorocyclopentadiene – specified POHC.

[i] Hexachlorethane – specified POHC.

[j] Hexachlorobenzene – specified POHC.

RECEPTOR GRID

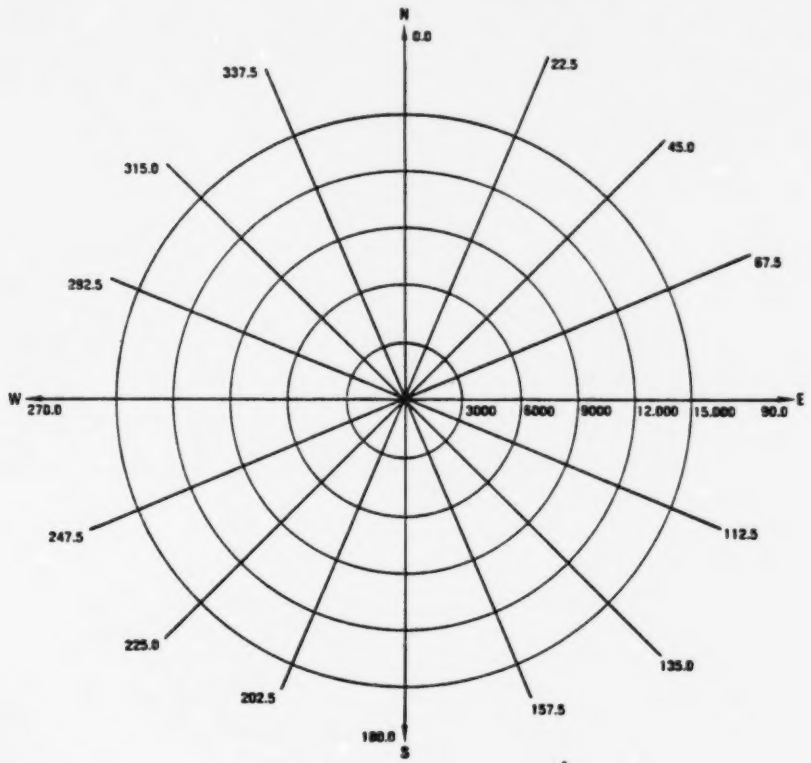

FIGURE 2

hydrocarbon (HC) releases and for release values of six specified principal organic hazardous constituents (POHCs). Concentrations at the 176 receptors were calculated for each of three sources and total for the seven pollutants (HC + 6 POHCs). The three sources were stack emissions, fugitive emissions from the incinerator structure, and fugitive emissions from the tank farm area.

Total Hydrocarbon Air Concentration

For all directions, the maximum concentration occurred immediately downwind. Not surprisingly, the average concentrations decrease rapidly with distance to less than 2 percent of the maximum at a distance of 12.5 km downwind.

Contribution of Sources to HC Concentration

As one might expect, the relative contribution to total ground level HC by each of the three release types varies with both distance and direction from the facility. Table 2 summarizes the relative contribution of each of the three sources to total ground level air concentration of HC as a function of distance.

POHC Air Concentration

With fugitive and stack data available for six POHCs, a more detailed emission/exposure assessment is possible. Table 3 contains maximum concentration and location data for six identified POHCs. The largest POHC concentration is 1.86×10^{-3} $\mu g/m^3$ (3.75×10^{-7} ppm) of chloroform ($CHCl_3$) occurring in the sector segment described by the centroid location of 250 m from the incinerator on an angle of 348.75° clockwise from due north. This concentration is very low, as is the concentration of the most toxic POHC, hexachlorocyclopentadiene (HCCP), which has a maximum concentration of 1.75×10^{-5} $\mu g/m^3$ (1.54×10^{-9} ppm).

Population Exposure to POHC

Exposures to POHCs are also very low. Total exposure (person-$\mu g/m^3$) ranges from 1.05 for C_6Cl_6 to 38.7 for $CHCl_3$ while average individual exposure (person-$\mu g/m^3$) ranges from 1.19×10^{-6} for C_6Cl_6 to 4.41×10^{-5} for $CHCl_3$. Table 4 also contains the total exposure and average individual exposure to each POHC from each source. Clearly, most POHC exposure is due to stack releases, but significant exposure can also be due to fugitive releases when the POHC is volatile ($CHCL_3$ and CCl_4 have the highest vapor pressure of the identified POHCs so their fugitive emission rates are higher). For example, over 14 percent of total exposure to $CHCl_3$ is caused by fugitive releases whereas only about 0.03 percent of total exposure to semi-volatile C_6Cl_6 is caused by fugitive releases.

CONCLUSIONS

Public exposure to HC from this incinerator is low. An assessment of emission sources shows that from the site 89.8 percent of total exposure to HC is due to stack emissions, but that for locations close to the incinerator, fugitive HC sources may dominate (5). Perhaps, because they are emitted near the ground, fugitive emissions have a disproportionately high effect on close-in population exposure.

The methodology employed to measure fugitive emissions has limitations in accuracy and composition identification. For example, actual samples could have been taken of the gas emitted from fugitive leaks to verify the chemical composition of the leak and the leak rate, but shortages of both time and money prevented this. Nevertheless, results of this study are useful. Not only are future research areas defined, but also this study is based on measured data which, with future measurement, can be used to characterize emissions from hazardous waste incinerators.

The emission assessment used data from a test burn for a very well run incinerator which achieved destruction efficiencies that met or exceeded the 99.99 percent DRE standard. (In addition, the facility was new and, therefore, would not be expected to have as many fugitive emissions as an older less well maintained facility.) This data reflects only one day of operation which is extrapolated to annual operation, a simplifying assumption that may lead to large source term inaccuracies. The validity of this assumption needs to be studied. The possibility of large, short-term releases due to accidents, spills, and sprays should also be investigated. If it is assumed that day to day operation is similar to test burn conditions, then it seems reasonable to conclude that normal incinerator operation at or exceeding the standard levels produces minimum HC emissions. Conclusions

Table 2. Fractional contribution of each source to total ground level air concentration of HC

Distance (m)	Stack		Structure		Tank farm	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
200	0.348	0.929	0.003	0.050	0.039	0.648
300	0.409	0.946	0.004	0.037	0.034	0.587
500	0.521	0.932	0.007	0.023	0.052	0.471
700	0.596	0.919	0.009	0.018	0.068	0.393
1,000	0.674	0.901	0.010	0.015	0.086	0.314
2,000	0.774	0.915	0.008	0.011	0.076	0.215
3,000	0.816	0.917	0.007	0.010	0.076	0.174
5,000	0.867	0.920	0.006	0.008	0.073	0.125
7,000	0.874	0.922	0.006	0.008	0.072	0.118
10,000	0.918	0.923	0.006	0.006	0.071	0.076
15,000	0.921	0.925	0.005	0.006	0.070	0.073

TABLE 3

LOCATIONS AND VALUES OF MAXIMUM AVERAGE GROUND LEVEL AIR CONCENTRATIONS

POLLUTANT	SOURCE	CONCENTRATION, MICROGRAMS PER CUBIC METER	LOCATION OF CENTROID	
			DEGREES FROM NORTH	METERS FROM ORIGIN
CHCL3	STACK	1.33E-03	348.75	250.00
CHCL3	STRUCTURE	5.59E-05	326.25	250.00
CHCL3	TANK FARM	7.32E-04	11.25	250.00
CHCL3	ALL SOURCES	1.86E-03	348.75	250.00
CCL4	STACK	1.80E-04	348.75	250.00
CCL4	STRUCTURE	2.27E-05	326.25	250.00
CCL4	TANK FARM	2.98E-04	11.25	250.00
CCL4	ALL SOURCES	4.52E-04	11.25	250.00
C2CL4	STACK	7.82E-04	348.75	250.00
C2CL4	STRUCTURE	1.21E-06	326.25	250.00
C2CL4	TANK FARM	1.58E-05	11.25	250.00
C2CL4	ALL SOURCES	7.93E-04	348.75	250.00
HCCP	STACK	1.67E-05	348.75	250.00
HCCP	STRUCTURE	7.31E-08	326.25	250.00
HCCP	TANK FARM	9.53E-07	11.25	250.00
HCCP	ALL SOURCES	1.75E-05	348.75	250.00
C2CL6	STACK	4.54E-05	348.75	250.00
C2CL6	STRUCTURE	1.62E-08	326.25	250.00
C2CL6	TANK FARM	2.12E-07	11.25	250.00
C2CL6	ALL SOURCES	4.56E-05	348.75	250.00
C6CL6	STACK	4.20E-05	348.75	250.00
C6CL6	STRUCTURE	3.21E-09	326.25	250.00
C6CL6	TANK FARM	4.19E-08	11.25	250.00
C6CL6	ALL SOURCES	4.21E-05	348.75	250.00

TABLE 4

SUMMARY OF EXPOSURES TO 877641. PERSONS AT
CINCINNATI MSD INCINERATOR - POHC RUN

POLLUTANT	SOURCE	TOTAL EXPOSURE, PERSON*UG/M**3	AVERAGE INDIVIDUAL EXPOSURE, UG/M**3
CHCL3	STACK	3.30E+01	3.75E-05
CHCL3	STRUCTURE	4.33E-01	4.94E-07
CHCL3	TANK FARM	5.22E+00	5.95E-06
CHCL3	ALL SOURCES	3.87E+01	4.41E-05
CCL4	STACK	4.47E+00	5.09E-06
CCL4	STRUCTURE	1.76E-01	2.01E-07
CCL4	TANK FARM	2.13E+00	2.42E-06
CCL4	ALL SOURCES	6.80E+00	7.74E-06
C2CL4	STACK	1.94E+01	2.22E-05
C2CL4	STRUCTURE	9.35E-03	1.07E-08
C2CL4	TANK FARM	1.13E-01	1.28E-07
C2CL4	ALL SOURCES	1.96E+01	2.23E-05
HCCP	STACK	4.16E-01	4.74E-07
HCCP	STRUCTURE	5.66E-04	6.45E-10
HCCP	TANK FARM	6.82E-03	7.78E-09
HCCP	ALL SOURCES	4.23E-01	4.82E-07
C2CL6	STACK	1.13E+00	1.29E-06
C2CL6	STRUCTURE	1.26E-04	1.43E-10
C2CL6	TANK FARM	1.51E-03	1.73E-09
C2CL6	ALL SOURCES	1.13E+00	1.29E-06
C6CL6	STACK	1.05E+00	1.19E-06
C6CL6	STRUCTURE	2.49E-05	2.83E-11
C6CL6	TANK FARM	3.00E-04	3.42E-10
C6CL6	ALL SOURCES	1.05E+00	1.19E-06
ALL HC	STACK	3.60E+04	4.10E-02
ALL HC	STRUCTURE	3.12E+02	3.55E-04
ALL HC	TANK FARM	3.76E+03	4.28E-03
ALL HC	ALL SOURCES	4.01E+04	4.57E-02

concerning total hydrocarbon exposure require additional qualitative and quantitative composition analyses.

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